Partitioning of Chemical and Physical Effects of Earthworm on Growth Performance of the Vegetable Amaranthus

Article *in* Australian Journal of Basic and Applied Sciences · August 2010

Gabriel A. Dedeke
University of Agriculture, Abeokuta

Senjobi Bolarinwa Ayoola
University of Agriculture, Abeokuta

Adeyinka Aladesida
University of Agriculture, Abeokuta

Australian Journal of Basic and Applied Sciences, 4(8): 3755-3761, 2010
ISSN 1991-8178

Partitioning of Chemical and Physical Effects of Earthworms on Growth Performance of the Vegetable *Amaranthus*

[1]Owa, S.O., [1]Dedeke, G.A., [1]Moreyibi, O.H., [2]Morafa, S.O.A.,
[2]Senjobi, B.A and [1]Aladesida, A.A.

[1]Department of Plant Science and Applied Zoology, Olabisi Onabanjo University,
Ago-Iwoye, Nigeria.
[2]Department of Soil Science and Farm Mechanization, Olabisi Onabanjo University, Ago-Iwoye.

Abstract: This study was carried out to partition the physical and chemical effects of earthworms on the vegetable crop *Amaranthus*. By restricting earthworms to one half side of plant pots and comparing plant growth performance on both sides of the pots, and by comparing these with completely wormless pots (control), statistical analyses showed that plants on the wormless sides of wormed pots perform better than those in control pots. This suggests that some earthworm products cross the cloth septa to positively influence the plants on the wormless sides. The differences represents the effect due to chemical products of earthworms or of their activities. Plants on the worm sides of pots perform better than those on the wormless sides. Their difference represents the physical effects of the earthworms. It is estimated that chemical effects of the earthworms *Libyodrilus violaceus* improve *Amaranthus* performance by about 32% and the physical effects by about 36%. The total effect of both amount to about 68%. The growth parameter significantly improved are: plant height, leaf length, leaf area and number of leaves, whereas stem girth and leaf width are not significantly affected. This suggests that some chemical product of the earthworms affect primary apical meristem in the cell proliferation and elongation zones. This agrees with the suggestion that earthworms produce auxins and cytokinins. The estimated optimal level of earthworm treatment was 15 earthworms per pot (equivalent to 3.77million worms/ha, or 0.38T/ha for *L. violaceus*). For *Amaranthus* the parameters most improved by the earthworms were those that most affected market value. This should therefore be a good campaign factor to encourage farmers to adopt earthworm transplatation as a partial substitute for application of inorganic fertilizers.

Key words:

INTRODUCTION

It has been widely established that earthworms positively affect agroecosystems. Among the reported effects are that earthworms form appropriate soil aggregates that inhibit both erosion and soil compaction (Tynes, M.J., 2001). By improving soil fertility they reduce dependence on inorganic soil fertilizers (Lake, E. and Supak, S., 1996). They improve soil water conservation (Curry, J.P and Good, J.A., 1992). Soil moisture retention in sandy soils is improved due to their wormcasts that increase the clay fraction of the soil (Ruz Jerez, E., *et al.*, 1988). They stabilize soil pH which, in turn improves soil nutrient availability (Ruz Jerez, E., *et al.*, 1988). Their burrowing activities result in easier penetrability of soil plant roots (Kladivko, E.J and Timmenga, H.J., 1990; Zachman, J.E and Linden, D.R., 1989). This is especially important in clayey soils. Drainage of clayey soils is also improved (Joschko, M., *et al.*, 1989). By improving soil structure, porosity and density, earthworms stimulate plant root health and growth. By feeding on soil microbes earthworms control the effects of the pathogenic ones (Raj, H and Bhardwaj, M.L., 2001; Yeates, G.W., 1981).

By their burrowing activities, earthworms create a gallery of channels in the soil, even in harpan and compacted soil. This, in turn, lead to good aeration of the soil and consequently, good root respiration and ultimately good crop performance. Good water absorption resulting from earthworm activities means less water runoff that could leach nutrients, or wash off the top soil.

Corresponding Author: Dedeke, G.A 1Department of Plant Science and Applied Zoology, Olabisi Onabanjo University, Ago-Iwoye, Nigeria
E-mail: bisiwunmiddk@yahoo.com

With the facilitating effect of earthworms burrowing activities, roots can grow much faster, as much as 7 inches per day (Tynes, M.J., 2001). Root growth and development are further facilitated by the wormcasts formed around the roots, because the casts are a rich source of soil nutrients (Tynes, M.J., 2001). Not only do earthworms convert plant waste materials and litters to humus, they proceed further to convert the humus to casting materials. Whereas the catabolic products of decaying plant materials include phenols and aldehydes, both of which are inhibitory to plant growth and health, earthworms convert them into auxins and cytokinins which are plant growth hormones (Ruz Jerez, E., *et al.*, 1988).

It has been estimated that wormcasts contains as much as ten times the amount of solubleb plant available nutrients as in the soil (Tynes, M.J., 2001). The polysaccharide produced by earthworms bind sandy soil into good aggregates that resist rapid drainage. On the other hand, clayey soils are broken into adequate soil aggregates that improve their drainage and aeration. By a combination of these processes earthworms improve the performance of crops.

Our objective in the present study is to quantitatively partition the effect of earthworm on the vegetable crop *Amaranthus* into chemical and physical components.

MATERIALS AND METHODS

Soil Preparation:

Sandy loamy soil collected from the Temporary Farm of the Rice Development Project, Olabisi Onabanjo University, Ago-Iwoye, was dry-heat sterilized at about 104 ^{0}C for about 4 hr

Preparation of Plant Pots:

Plastic bowls (22.5 cm diameter, 10 cm height (surface area 3.975 X 10^{-6} ha)) were used as plant pots. Polyester cloth bags were sewn with a vertical septum to divide each bag into two equal halves. A bag each was placed in the pots. 820 g of the sterilized soil was loaded into each half of the pot.

Earthworms:

Libyodrilus violaceus Beddard was collected from the bank of a local stream. Graduated numbers (and masses) of the earthworm (Table 1) were introduced into the plant pots. The earthworms were introduced into only one side of each pot which is hereunder referred to as the worm side. The other half pot lacked earthworms and are hereunder called wormless sides. There were five replicates of each level of worm treatment.

Table 1:

	Number of worms per pot		Wet mass of worms per pot	
S/N	Number	Equivalent in million worm/ha	Mass	Equivalent in T/ha
1	0 (control)	0	0.000	0.000
2	5	1.26	0.502	0.126
3	10	2.52	0.852	0.214
4	15	3.77	1.512	0.380
5	25	6.25	3.012	3.011

Water 1.2 L was applied to each pot via the worm sides and the pots were setup and left for three days in a green house. On the fourth day 10 seeds of *Amaranthus* were planted at about 0.5 cm depth on each side of the pots. 200 ml of water, collected from a surface well within the Rice Farm, was subsequently applied to the setup every other day.

The parameters measured include plant height, stem girth, leaf length, leaf width, average leaf area, total leaf area and the total number of leaves. These measurements were taken five times at four days intervals. Records were taken separately for the wormsides and wormless sides of each pots.

Statistical Analyses:

The results obtained were computer-analyzed using the Statistical Package for Social Sciences (SPSS version 10.1, SPSS Inc, 1999). The following comparisons were made:

- The differences in performance between the worm and wormless sides were compared using the Student's T-test. This test enabled us to separate the chemical effects of earthworms from the physical effects. It is assumed that equilibrium of the concentration of earthworm products should be the same on both sides of the wormed pots.

- Similarly, difference between pots treated with different levels of earthworms were tested using ANOVA. The results of this test enabled us to estimate the optimal level of earthworms required in the soil.
- Performance in the 0-worm pots (control pots that lack earthworms on either side) were compared with performance on the wormless sides (of the worm pot using the T-test. This was to reveal if some soluble product of earthworms or of their activities cross the cloth septa to influence plant growth performance. The difference between them was an estimate of the plant growth performance due to chemical effect of the earthworms.
- By studying what growth parameters are affected and how, it was possible to determine the involvement of some plant growth hormone(s)

RESULTS AND DISCUSSION

Results:

Comparing Control (0-worm) and the Wormless Sides (Of Wormed Pots):

Table 2 showed that plants on the wormless sides of wormed pots performed better than those in the control pots. This indicates that some earthworm products or a product of their activities crosses the cloth septa to positively affect the plants on the wormless sides. The product must therefore be water soluble.

Table 2: Plant growth performance in 0-worm (control) pots compared with performance on the wormless sides of worm pots Record taken days after planting

Parameter		day	day	day	day	day	Mean gain (as % of control)
Plant height (cm)	0-worm	3.56	4.14	5.39	6.53	8.52	
	Wormless side	5.11	5.72	7.42	9.11	10.84	
	Statistical test	S	S	S	S	S	
	% gain	43.54	38.16	37.66	39.51	27.23	37.22
Stem girth (cm)	0-worm	0.22	2.31	2.96	2.44	2.32	
	Wormless side	3.13	3.57	4.20	4.69	5.11	
	Statistical test	S	N	N	N	N	
	% gain	204.55	35.93	-11.49	-5.33	-6.47	43.44
Leaf length (cm)	0-worm	2.64	2.80	3.34	3.78	4.37	
	Wormless side	3.13	3.57	4.20	4.69	5.11	
	Statistical test	S	S	S		S	
	% gain	18.56	27.50	25.75	24.07	16.93	22.56
Leaf width (cm)	0-worm	1.19	2.08	2.05	2.12	2.43	
	Wormless side	1.49	1.90	2.10	2.32	2.45	
	Statistical test	N	N	N	N	N	
	% gain	25.21	-8.665	2.44	9.43	0.82	5.85
Mean leaf area (cm^2)	0-worm	1.08	1.82	3.44	2.24	2.24	
	Wormless side	1.73	2.41	3.95	3.18	3.18	
	Statistical test	N	N	S	S	S	
	% gain	60.19	32.42	14.83	41.96	41.96	38.27
No of leaves	0-worm	2.67	2.83	2.24	4.05	4.82	
	Wormless side	2.68	3.41	3.18	4.58	5.21	
	Statistical test	N	S	N	N	N	
	% gain	0.37	20.49	41.96	13.09	8.09	16.80
Total leaf area (cm^2)	0-worm	3.06	7.97	8.34	14.15	23.65	
	Wormless side	5.06	9.17	14.51	21.53	28.93	
	Statistical test	N	S	S	S	N	
	% gain	65.36	84.51	73.98	52.16	22.33	59.67

Comparing Worm and Wormless Sides of Wormed Pot:

Table 2 showed that plant height were considerably higher on the worm side than on the wormless sides. Stem girth was usually higher on the wormless sides than on the worm sides, even though the differences were not statistically significant. The responsible factor may be diverting growth efforts more towards cell proliferation and elongation than towards lateral growth. Leaf length was regularly longer on the worm sides than on the wormless sides. Leaf width was consistently wider on the worm sides than on the wormless sides even though statistically insignificant. Number of leaves per plant was considerably higher on the worm sides than on the wormless sides. Mean and total leaf area were consistently higher on the worm sides than on the wormless sides.

Effects of Levels of Earthworm Treatment:

Table 3 showed that the performance of the crop increases as the level of earthworm treatment. The differences caused were, however, statistically significant for only some of the parameters measured, viz stem height, leaf length, mean leaf area and total leaf area. Stem girth and leaf width were not significantly affected.

Table 3: Plant growth performance on wormless sides compared to worm sides of pots

Parameter		Record taken days after planting day	day	day	day	day	Mean gain (as % of control)
Plant height (cm)	0-worm	4.78	5.42	7.05	8.69	10.36	
	Wormless side	6.42	7.21	9.41	11.09	13.64	
	Statistical test	S	S	S	S	S	
	% gain	34.31	33.03	33.48	27.62	31.66	32.02
Stem girth (cm)	0-worm	0.59	3.09	2.83	2.45	2.28	
	Wormless side	0.84	2.05	2.17	2.00	2.08	
	Statistical test	N	V	N	N	N	
	% gain	42.37	-33.68	-23.32	-18.37	-8.77	-8.35
Leaf length (cm)	0-worm	3.06	3.44	4.06	4.56	4.96	
	Wormless side	3.62	4.24	4.98	5.40	6.08	
	Statistical test	N	S	S	S	S	
	% gain	18.30	23.26	22.66	18.42	22.58	21.04
Leaf width (cm)	0-worm	1.44	2.22	2.15	2.34	2.45	
	Wormless side	1.66	2.12	2.44	2.66	3.03	
	Statistical test	N	N	N	V	S	
	% gain	15.28	4.95	13.49	13.68	23.67	14.21
Mean leaf area (cm^2)	0-worm	1.63	2.37	3.07	3.07	3.07	
	Wormless side	2.31	3.39	4.70	4.70	4.77	
	Statistical test	N	S	S	S	S	
	% gain	41.72	43.04	53.09	53.09	55.37	49.26
No of leaves	0-worm	2.70	3.31	3.86	4.52	5.13	
	Wormless side	3.42	4.28	5.00	5.52	6.52	
	Statistical test	N	S	S	S	S	
	% gain	26.67	29.31	29.53	22.12	27.10	
Total leaf area (cm^2)	0-worm	4.76	8.58	13.57	20.57	27.47	
	Wormless side	9.91	18.65	30.90	43.80	58.93	
	Statistical test	S	S	S	S	S	
	% gain	108.19	117.37	127.71	112.93	114.52	116.14

Percentage Gains Due to Chemical and Physical Effects of Earthworms and Their Physical Impact:

Table 4 showed that the earthworm *L. violaceus* causes as much as 69% gain in the height of *Amaranthus*, about 44% gain in the number of leaves and about 175% gain in the total leaf area.

The average gain by *Amaranthus* due to chemical effects of earthworm was about 32% and that due to physical effects of the earthworm *L. violaceus* was about 36%. The total gain due to both groups of activities is about 68%.

Optimal Level of Earthworm Treatment:

As the levels of earthworm treatment increases from zero (control) to 10-worms per pot, the effects on total leaf area and other parameters rise slowly. But between 10-worm and 15-worm there was a sharp rise in the effect on the growth parameters. Beyond 15-worm level a plateau followed. The growth response to increase in earthworm level was therefore sigmoid. The pattern was true of all the growth parameters measured. Therefore, in terms of net gain per effect the 15-worm level of treatment was optimal.

Discussion:

This study juxtaposing earthworms and plants, facilitate the conclusion that some products of earthworms or of their activities enhance plant growth. From the results of the performance of control plants compared with plants on the wormless sides of the worm pots, it is concluded that the growth factor involves chemical products that are water soluble and readily diffuse across the cloth septa.

Optimal Level of Earthworm Treatment:

The determination of 15-worm level (3.77 million worm/ha) as optimal is a useful piece of information. Owa and Olojo (Unpublished data) have found that the average level of *L. violaceus* in some Nigerian soils is ablout 0.375 T/ha. They were of the opinion that *L. violaceus* along with other limicolous earthworms make major contributions to the productivity of the many river basin agricultural projects in Nigeria.

Table 4: Effect of level of earthworm treatments on plant growth performance

Parameter		*First mean*	*Second mean*	*Third mean*	*Fourth mean*	*Fifth mean*
Plant height (cm)	0-worm	3.56	4.14	6.39	6.53	8.52
	5-worm	3.5	3.26	6.18	6.27	9.44
	10-worm	7.13	7.22	9.26	10.8	12.56
	15-worm	7.2	8.5	10.48	12.3	14.16
	25-worm	6.8	8.13	10.32	12.41	14.45
	Total	5.62	6.29	8.19	9.86	11.93
	Stat Test	S	S	S	S	S
Stem girth (cm)	0-worm	0.22	2.31	2.96	2.44	2.32
	5-worm	0.5	3.21	3.29	2.73	2.63
	10-worm	1.09	2.73	2.27	2.05	2.07
	15-worm	0.93	2.31	2.95	1.98	1.97
	25-worm	0.87	2.36	2.05	1.99	1.99
	Total	0.72	2.58	2.51	2.23	2.19
	Stat Test	S	N	N	N	N
Leaf length (cm)	0-worm	2.64	2.8	3.34	3.78	4.37
	5-worm	2.42	2.97	3.69	4.22	5.11
	10-worm	3.78	4.27	4.95	5.28	5.76
	15-worm	3.99	4.56	5.22	5.67	5.93
	25-worm	3.91	4.46	5.21	5.76	6.18
	Total	3.34	3.83	4.14	5.97	5.5
	Stat Test	S	S	S	S	S
Leaf width (cm)	0-worm	1.19	2.08	2.09	2.12	2.43
	5-worm	1.1	1.74	1.93	2.14	2.44
	10-worm	1.78	2.03	2.35	2.53	2.76
	15-worm	1.8	2.12	2.41	2.67	2.82
	25-worm	1.9	2.36	3.66	2.98	3.14
	Total	1.55	2.07	2.29	2.5	2.73
	Stat Test	S	N	N	S	S
Mean leaf area (cm^2)	0-worm	1.08	1.82	2.21	2.24	2.24
	5-worm	1.09	1.89	2.61	2.65	2.75
	10-worm	2.41	3.16	4.31	4.3	4.3
	15-worm	2.58	3.59	4.76	4.76	4.76
	25-worm	2.73	3.76	5.14	5.14	5.14
	Total	1.98	2.37	3.86	3.85	3.88
	Stat Test	S	S	S	S	S
Number of leaves	0-worm	2.62	2.83	3.41	4.65	4.32
	5-worm	2.7	3.26	3.8	4.47	5.49
	10-worm	4.58	4.71	5.04	5.47	6.18
	15-worm	1.9	3.5	4.47	5.18	5.9
	25-worm	3.9	4.65	5.2	5.8	6.5
	Total	3.06	3.79	4.41	5.01	5.79
	Stat Test	S	S	S	S	S
Total leaf area (cm^2)	0-worm	3.06	4.97	8.34	14.15	23.65
	5-worm	3.72	7.26	12.73	21.75	34.6
	10-worm	12.72	17.58	25.88	34.29	42.72
	15-worm	5.11	16.28	27.73	37.44	45.55
	25-worm	12.92	20.9	33.54	50.44	63.41
	Total	8.39	13.51	21.93	31.83	42.52
	Stat Test	S	S	S	S	S

Table 5: Percentage gain due to chemical products of earthworms and their physical impact

Growth parameter	[1]Percentage gain attributable to chemical products of earthworms	[2]Percentage gain attributable to physical effects of earthworms	[3]Total Percentage gain due to both chemical and physical effects of earthworms	
Plant height	37.22	32.02	69.24	
Stem girth	43.44	-8.35	35.09	
Leaf length	22.56	21.04	43.61	
Leaf width	5.82	14.21	20.06	
Mean leaf area	38.27	49.26	87.54	
Mean number of leaves per plant		16.80	26.95	43.75
Total leaf area	31.97	35.90	67.87	

[1]ie, Worm sides relative to 0-worm
[2] ie, Worm sides relative to worm sides
[3]ie, Worm sides relative to 0-worm

Gains in Growth Parameters:

The greatest gain due to earthworms affect lengthwise parameters: plant height, leaf length and leaf area. These are basically characters affected by primary meristematic tissues. It also suggests that the effective products of the earthworms very probably have their effects on cell multiplication and elongation regions of apices of plant and leaves. The reduced effect on stem girth and leaf width suggests that the effective products may not affect secondary growth thickening.

The pattern of effect suggests that prime among the products are auxin and cytokinins. It has earlier been observed that earthworms by their activites prevent the usual conversion of plant wastes to phenols and aldehydes by rather converting them to humus and secondarily converting humus to auxin and cytokinins (Ruz Jerez, E., *et al.,* 1988; Tynes, M.J., 2001).

Nutritional Hormonal Effects of Earthworms:

Two groups of chemical may be involved in the observed effects of earthworm on plant growth: nutritional and hormonal. Nutritional products of earthworm activities include the conversion of plant materials to humus and fertilization of the conversion of plant materials to readily available N, S and P which then act as fertilizers and nutrients for the formation of amino acids, proteins, nucleic acids and chlorophyll precursor (Ruz Jerez, E., *et al.,* 1988). Their hormonal effect involve the conversion of humus into the plant growth hormones mentioned above.

The Physical Effects of Earthworm:

The present results indicate that the percentage gain attributable to physical effects of earthworms (about 36%) is greater than that attributable to their chemical effects (about 32%). The mechanism of these have been highlighted in the introduction to this paper. Incidentally, the species *L. violaceus* used in this experiment is a poor wormcast maker. It may not form surface cast if the habitat is not flooded. And when it does, the cast is of the massy type. The species has been identified from most part of southern and middle regions of Nigeria (Owa, S.O., 1992). This ratio of (chemical : physical) contribution is likely to be different if a turret-caster type of earthworm is used, and perhaps, also, the total contribution of both factors to plant performance.

Effects on the Number of Leaves:

That earthworm treatment increases the number of leaves is also noteworthy. It could be that an extension of their chemical effects is to stimulate the normally dormant leaf bud. This will be in line with the functions of the plant growth hormones that affect apical growth (Ruz Jerez, E., *et al.,* 1988).

Market Implication of the Gain in Plant Height, Leaf Length and Leaf Area:

It is noteworthy that the growth parameters most positively affected are those that most affect the market values of the leafy vegetable *Amaranthus* viz plant length (height), number of leaves and leaf area. In most part of Nigeria, the leaves, petioles and succulent stem are consumed as food. If enough quantity of earthworm can be guaranteed, it should therefore be easy to convince *Amaranthus* farmers to transplant earthworms into their farms and gardens

REFERENCES

Curry, J.P. and J.A. Good, 1992. Soil Fauna Degradation and Restoration. Advances in Soil Science., 17: 171-215

Joschko, M., H. Diestel and O. Larink, 1989. Assessment of earthworm burrowing efficiency in compacted soil with a combination of morphological and soil physical measurements. Biol. Fert. Soils, 8: 191-196.

Kladivko, E.J. and H.J. Timmenga, 1990. Earthworms and agricultural management. In: Box, J.E and L.C. Hammond (eds). *Rhizosphere Dynamics.* Westview Press. CO.

Lake, E. and S. Supak, 1996. What's the deal with yucky old worms? Sierra Peloma Press., pp: 1-2.

Owa, S.O., 1992. Taxonomy of Nigerian earthworms of the family Eudrilidae and their use as possible indicators of soil properties, PhD Thesis. Obafemi Awolowo University, Ile-Ife, Nigeria.

Raj, H. and M.L. Bhardwaj, 2001. Earthworms' role in soil biology

Ruz, Jerez, E., P.R. Ball and R.W. Tillman, 1988. The role of earthworms in nitrogen release from herbage residues. In Jenkinson, D.S and K.A Smith (eds). Nitrogen efficiency in Agricultural Soils. (publisher unknown) pp: 353-370.

Tynes, M.J., 2001. http://www.mastercomposter.com

Yeates, G.W., 1981. Soil nematode populations depressed in the presence of earthworms *Pedobiologia*, 22: 191-195.

Zachman, J.E. and D.R. Linden, 1989. Earthworm effects on corn residue breakdown and infiltration. Soil Sci. Soc. Am., 53(6): 1846-1849.